The Application of Two Tsunami Inundation Model in the Kuta Mandalika Coast

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Abstract. The analysis of tsunami inundation is the part of tsunami threat study. In the manual of the Disaster Prevention National Agency (DPNA), the tsunami inundation can be analyzed by the Berryman Method. The method calculates the tsunami wave height reduction when inundating the land based on the surface roughness and land slope. Another method for analyzing tsunami inundation is the wave simulation by using the COMCOT Model. The model simulates the generation, propagation, and inundation of waves based on bathymetry and topography. These two models were applied in the Kuta Mandalika. The land use map, the bathymetry and the topography of Kuta Mandalika were utilized. In the COMCOT Model result, the tsunami inundation reaches 1.2 km from the Kuta Beachline and 1.9 km from the Seger Beachline. The tsunami inundation area is 4.4 km^2 or 19% of the Kuta Village area. In the Berryman Method result, the tsunami inundation reaches about 250 m from the Kuta Beachline and 180 m from the Seger Beachline. The tsunami inundation area is 0.36 km^2 or 2% of the Kuta Village area. The Berryman Method result is underestimated compare with the COMCOT Model. The Berryman Method should be applied carefully in the tsunami inundation analysis.

Keywords: tsunami · inundation · COMCOT · Berryman · Mandalika

1 Introduction

The Kuta Coast is located in Kuta Village, Pujut, Central Lombok District, West Nusa Tenggara Province. It became part of Mandalika Super Priority Tourism Destination in 2014 based on government regulation [1]. Due to that reason, it is named the Kuta Mandalika Coast. The prime sector is maritime tourism, MICE (Meeting, Incentive, Convention, Exhibition), and cultural tourism. The international race circuit has also been built and already performed the World Super Bike (WSBK) and MotoGP. The government appointed the Indonesia Tourism Development Corporation (ITDC) as an operator. As a consequence of high utilization, the population will increase in that area.

However, the Kuta Mandalika Coast has the tsunami disaster risk. This area had been hit the earthquake and tsunami in 1977 [2] [3]. There have been many efforts to do disaster

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mitigation by operator, government agency, research and high education institution. The analysis of tsunami threat is one of disaster mitigation effort. The tsunami inundation analyzing is one way of that.

The analysis of tsunami inundation can be perform in many ways. The simplest one use the principal of similar elevation between tsunami height and land elevation. The sophisticated one use the wave simulation. The Disaster Prevention National Agency (DPNA) had published the technical manual of tsunami disaster risk analysis [4]. In the manual, the tsunami inundation can be analyzed by using Berryman Method. The wave simulation had been utilized in the Kuta Mandalika by using COMCOT Model [5] [6].

In this article, the comparation between the Berryman Method and COMCOT Model will be performed in the case of Kuta Mandalika. The result differences will be point out and the application consideration will be stressed.

2 Methodology

2.1 Berryman Model

Berryman developed the calculation of flood inundation based on the water elevation loss [7]. The elevation loss every 1 m spacing is influenced by the land slope and surface roughness, as follows:

$$H_{loss} = \left(\frac{167n^2}{H_0^{1/3}}\right) + 5\sin S \tag{1}$$

With:
H_{loos} = water elevation loss every 1 m spacing (m)
n = surface roughness coefficient
H_0 = tsunami wave height along coastline (m)
S = land slope (degree)

The surface roughness coefficient is based on the land use area. Table 1 shows the list of surface roughness coefficient.

2.2 COMCOT Model

Cornell Multigrid Coupled Tsunami (COMCOT) Model was developed by Professor Phillip L-F Liu from Cornell University [8]. The model has capability to simulate the tsunami wave from generation, propagation on the sea and coastal land inundation. The wave propagation use the principal of shallow water equation, which is solved numerically by using finite different method. The model had been applied to analyze some tsunami events such as the Chile Tsunami in 1960, the Flores Tsunami in 1992 [9], the Aljazair Tsunami in 2003 [10], and the Hindia Ocean Tsunami in 2004 [11]. The COMCOT Model use data of bathymetry, topography, and initial wave generation or parameter.

Table 1. THE SURFACE ROUGHNESS COEFFICIENT

Land Use	Surface Roughness Coefficient
Water Body	0.007
Bush	0.040
Forest	0.070
Plantation	0.035
Empty Land	0.015
Farm	0.025
Settlement / Development	0.045
Mangrove	0.025

Fig. 1. The land use map of Kuta Mandalika (analysis)

2.3 Model Data

The model needs the reliable data to produce the good result. In the wave propagation analysis, the main important data are the spatial data which are consist of the land use map, topography and bathymetry.

1. The Kuta Land Use Map is from the West Nusa Tenggara Province as seen in Fig. 1. The land use of Kuta Mandalika was assumed as development area so that the roughness coefficient is 0,045. The Kuta Village area is about 23.66 km^2.
2. The topography and bathymetry data is from the ITDC with 10 x 10 m resolution. The data stretched between 116.27o - 116.33o E and 8.87o - 8.99o S. Figure 2 shows the topography map and Fig. 3 shows the bathymetry map of Kuta Mandalika.

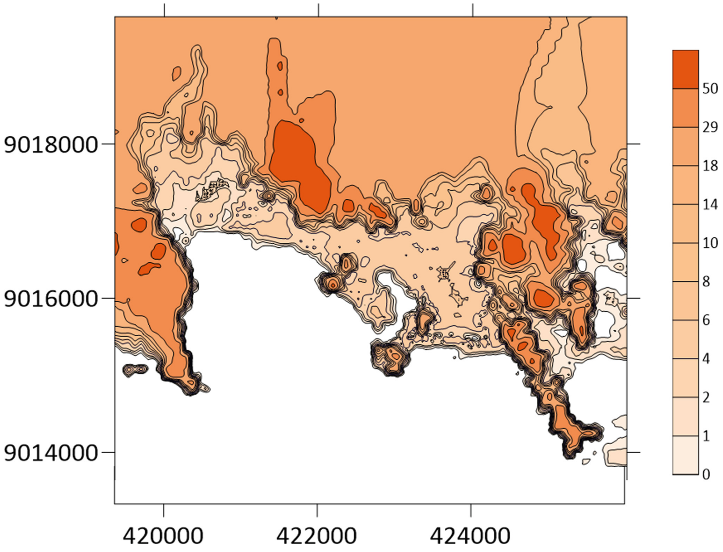

Fig. 2. The topography map of Kuta Mandalika (analysis)

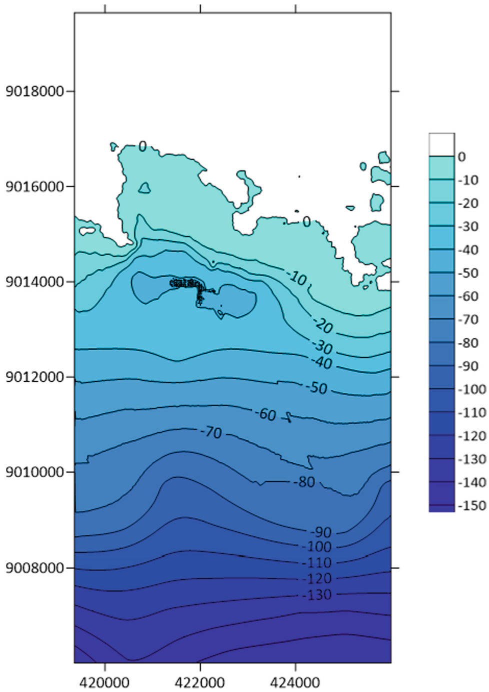

Fig. 3. The bathymetry map of Kuta Mandalika (analysis).

3 Results and Analysis

The COMCOT Model was run in 20 min of simulation time. Figure 4 shows the maximum reach of tsunami inundation which is obtained in the 14th minute. The maximum reach is 1.2 km from the Kuta Beach line and 1.9 km from the Seger Beach line. The maximum inundation depth can reach 3 m deep. The inundation area is 4.4 km^2 or 19% of the Kuta Village simulation area.

The COMCOT Model result gives the maximum tsunami height is 7 m along the Kuta Mandalika coastline. This wave height becomes the baseline of the Berryman Model. Figure 5 shows the land slope value of Kuta Mandalika area in the degree unit. It depicts the area as sloping from the beachline until the row of hills on the north side (2–3°).

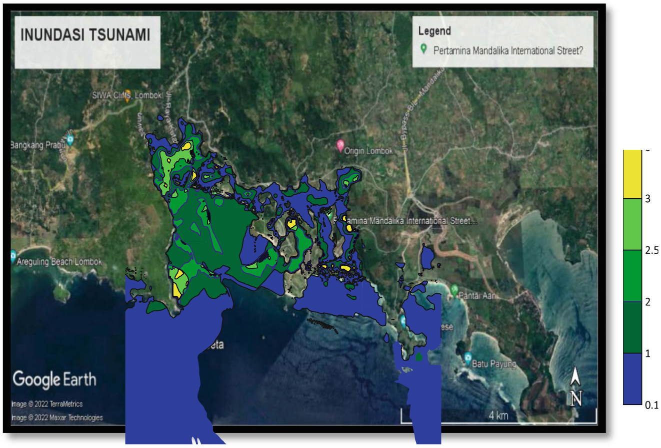

Fig. 4. The 14th-minute simulation result of COMCOT Model in Kuta Mandalika (analysis)

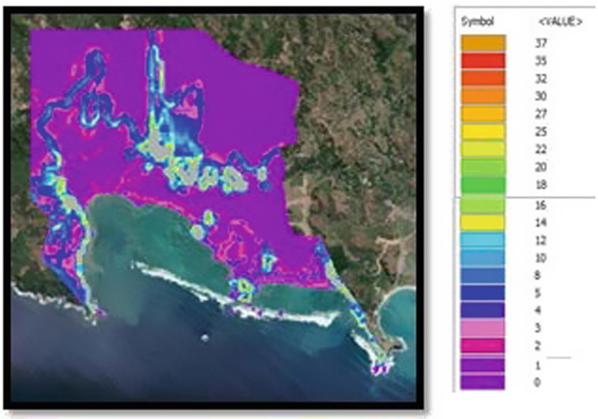

Fig. 5. The land slope value of Kuta Mandalika (in degree, analysis)

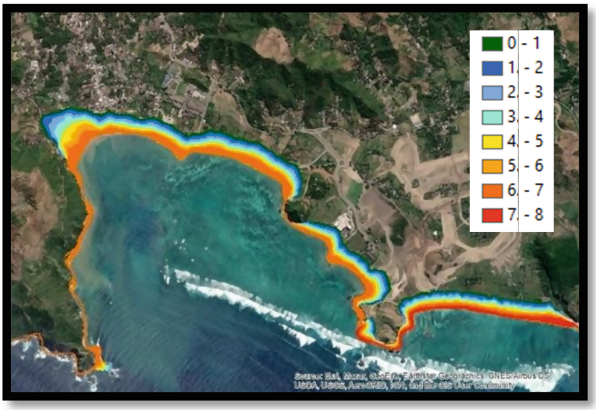

Fig. 6. The tsunami inundation area of Berryman Model in Kuta Mandalika (analysis)

Figure 6 shows the result of the tsunami inundation area from the Berryman Model. The maximum inundation reach is 470 m from the beach line. The average inundation is about 180–300 m along the beach line. The inundation area is 0.36 km^2 or 2% from the Kuta Village simulation area.

Figure 7 compares the result of the COMCOT Model (red area) and the Berryman Model (yellow area). It depicts that the Berryman Model result (2%) is very smaller than the COMCOT Model result (19%). It is about a one-tenth ratio. As written in Eq. 1, The Berryman Model calculates the reduction of wave height (Hloss). The reduction is influenced by the surface roughness (n), the tsunami wave height along the coastline (H0), and the land slope (S). Figure 8 shows the sensitivity of n and S values in the Berryman Model "(1)". For 1 m wave height, the S value influence dominantly the Hloss. However, the dominant influence changes significantly to the n value if the value is above 0,05.

As depicted in Fig. 7 the Berryman Model result is very smaller than the COMCOT Model. In terms of risk analysis, the Berryman Model result is underestimated. Whereas the Berryman Model is suggested in the DPNA technical manual. The Berryman Model is relatively simple equation so it is easy to apply. While the COMCOT Model is more complicated and need some high academic competence for applying it. However, the Berryman Model should be applied carefully especially in the coastal land which has most gentle condition.

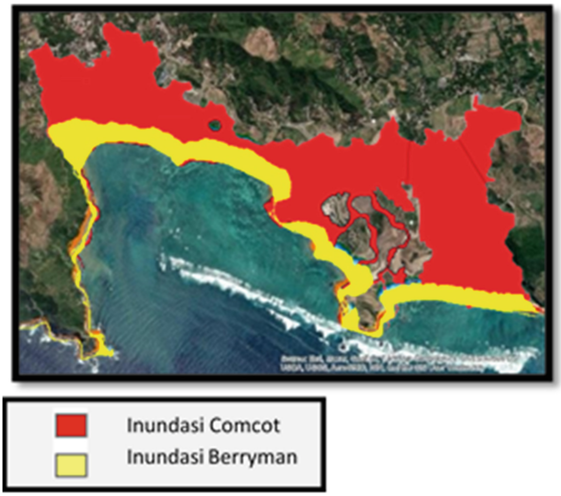

Fig. 7. The inundation area of Kuta Mandalika from COMCOT and Berryman Model (analysis)

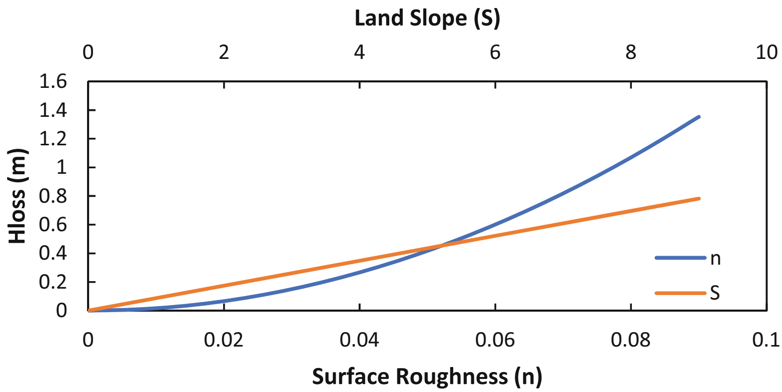

Fig. 8. The sensitivity of surface roughness and land slope in the Berryman Model (analysis)

4 Conclusion

The application of two tsunami models in the Kuta Mandalika has been presented. The results of Berryman Model and the COMCOT Model are 2% and 19% from the Kuta Village area respectively. The Berryman Model shows a smaller value than the COMCOT Model. The model is influenced significantly by the surface roughness and land slope. The Berryman Model may be applied in the tsunami inundation analysis carefully.

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